

SEND TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

1                   Enhanced Time-Based Proportional Control

2

3           FIELD OF THE INVENTION

4           This invention relates to time-based proportional  
5   control useful for chemical dosage control of water  
6   purification systems, such as the addition of chlorine to  
7   municipal swimming pools. The invention particularly relates  
8   to improvements in a time-based proportional control system  
9   for automating dosage control.

10

11           BACKGROUND OF THE INVENTION

12           Virtually all chemical dosage controllers marketed by  
13   U.S. Filter/Stranco within the last 10-12 years for use in  
14   the aquatic and industrial/municipal markets include a form  
15   of proportional chemical dosage control commonly referred to  
16   as Time-Based Proportional Control. Time-based proportional  
17   control has demonstrated usefulness for applications in  
18   cooling towers and other recirculated or batch systems that  
19   may experience dramatic loading swings.

20           Time-Based Proportional control was originally developed  
21   for use in spa applications where the chlorine demand will  
22   vary considerably due to small water volumes and the ratio of  
23   bodies/gallons of water in a spa. Standard on/off control for

1 this application was inadequate, as the only adjustment was  
2 the chlorine feed rate. On/off only control suffers from  
3 overshooting in either low loading situations, or inability  
4 to reach setpoint in high loading situations. A common method  
5 of addressing said overshooting is to manually adjust feed  
6 rates upwardly during the day and downwardly at night.

7 Time-Based Proportional control is basically a variation  
8 of on/off control which utilizes a relay output. Time-based  
9 proportional control utilizes a type of pulse width  
10 modulation effective to vary the duty cycle of the output  
11 relay on-time with respect to the deviation from setpoint.  
12 The duty cycle period is typically 30 seconds to one minute.  
13 As the sensor moves farther away from setpoint, the  
14 percentage of on-time per minute will increase. Conversely,  
15 the closer the sensor moves towards setpoint, the less the  
16 feeder operates per minute. Whenever the sensor of the  
17 controller exceeds setpoint, the feeder is always off.  
18 Recent improvements to this control have been the addition of  
19 an offset to keep the feeder from completely stopping until  
20 the setpoint is exceeded by some value and the ability to  
21 change the duty cycle period.

22 A deficiency of the time-based proportional control  
23 function is that it fails to operate efficiently because it

1 never reaches setpoint on high loading days-when it is needed  
2 the most.

3 Thus, what is lacking in the art is an ability to  
4 incorporate a form of deviation compensation which could be  
5 described as time-based proportional control with automatic  
6 offset, to thus include a functionality, having a relatively  
7 small number of resets per minute and a low sensitivity  
8 which, when incorporated therein, would eliminate the systems  
9 failure to achieve setpoint on high loadings days.

10  
11 SUMMARY OF THE INVENTION

12 The instant invention is a device and method for its use  
13 which includes the addition of a type of deviation  
14 compensation function which, in effect, provides an automatic  
15 offset ability which is effective for automatically adjusting  
16 the offset used in time-based proportional control. In  
17 practice actual offset adjustment is not always necessary.

18 An equivalent result is achievable by including a  
19 mathematical incrementation of the duty cycle ratio.

20 Inclusion of this improvement finds particular utility in  
21 situations like public pools where daily bather load varies  
22 depending on weather and other unpredictable factors.

23 Accordingly, it is an objective of the instant invention

1 to teach a method and device to enhance time-based  
2 proportional dosing of chemical additives by inclusion of a  
3 form of deviation compensation effective to approximate an  
4 ideal proportional control response.

5 It is a further objective of the invention to provide an  
6 ideal proportional control response by providing time based  
7 proportional control with automatic offset.

8 It is yet another objective of the instant invention to  
9 provide an ideal proportional control response by  
10 mathematically incrementing the duty cycle ratio.

11 It is a still further objective of the instant invention  
12 to provide ideal proportional control response by including  
13 integration of a measured signal.

14 Other objectives and advantages of this invention will  
15 become apparent from the following description taken in  
16 conjunction with the accompanying drawings wherein are set  
17 forth, by way of illustration and example, certain  
18 embodiments of this invention. The drawings constitute a  
19 part of this specification and include exemplary embodiments  
20 of the present invention and illustrate various objects and  
21 features thereof.

22  
23 BRIEF DESCRIPTION OF THE FIGURES

1 Figure 1 is a graphical representation of prior art on/off  
2 control;  
3 Figure 2 illustrates a typical on/off response curve;  
4 Figure 3 graphically illustrates chemical wastage;  
5 Figure 4 illustrates typical time-based proportional control;  
6 Figure 5, illustrates the ideal response of a Time Based  
7 Proportional control system;  
8 Figure 6 illustrates actual proportional control response  
9 with loading;  
10 Figure 7 shows the programmed response of the Time Based  
11 Proportional control with the addition of Integral response;  
12 Figure 8 is illustrative of the expected time-based  
13 proportional control with integral response in a typical HRR  
14 (High Resolution Redox) loading situation;  
15 Figure 9 is illustrative of a feed up example utilizing timed  
16 base proportional logic;  
17 Figure 10 modifies the prior art proportional logic mode of  
18 operation by including integration of a measured signal.

19  
20 DETAILED DESCRIPTION OF THE INVENTION

21 Time-Based Proportional control devices, for example  
22 devices available from USFilter/Stranco under the name  
23 STRANTROL are an improvement of the On/Off control method.

1 On/Off is commonly used for simple automatic process control.

2 To explain the improvement Time Based Proportional  
3 control provides, it is best to first explain the On/ Off  
4 control method and its limitations:

5 Note that in Figures 1-8 the X-axis represents time and  
6 the Y-axis represents the stated value but is not unit  
7 dependent, e.g. for proportional band width (PB), the  
8 graphical analysis is independent of whether the setpoint  
9 units are in mV, pH, microsiemens, or the like.

10 Now referring to Figure 1, On/Off control, as the name  
11 implies, has only two control states, ON and OFF. A  
12 disinfection control system feeding a chemical like Sodium  
13 Hypochlorite can be used as a good example. When the  
14 measured signal (HRR) is below the desired value (setpoint),  
15 the controller output is ON and stays on continuously until  
16 the measured signal meets or exceeds the setpoint. When the  
17 measured signal equals or exceeds the setpoint, the  
18 controller output changes to the OFF condition and the  
19 chemical feeder stops adding more chemical to the system.

20 With respect to specific chemical feeders, the  
21 controlling limitation is the ability of the feed system to  
22 tolerate a power on duty cycle of fractions of a minute.  
23 High current rotational motor driven pumps can be damaged by

1 short duty cycles such as 30 seconds on, 30 seconds off.  
2 Motor-operated ball valves also cannot tolerate short duty  
3 power applications. US Filter/Stranco utilizes Time-Based  
4 Proportional (TBP) control to regulate their patented CHF-150  
5 Calcium Hypochlorite feeder, along with a variety of brands  
6 of solenoid-motor diaphragm metering pumps. It is likewise  
7 within the purview of the instant invention to utilize time  
8 based proportional control to regulate peristaltic pumps from  
9 various manufacturers, solenoid valves that control water  
10 flow to venturi-type ejectors used to feed gaseous and liquid  
11 chemicals into water such as Chlorine, Sulfur Dioxide, Carbon  
12 Dioxide, and the like. Additionally, the use of TBP to  
13 control special duty solenoid valves that operate under  
14 pressure or vacuum to control chemicals (liquid and gaseous)  
15 fed, for example, to US Filter/Stranco's patented WATER CHAMP  
16 gas induction feeders, CO<sub>2</sub> feeders and the like are also  
17 contemplated.

18 As further illustrated in Figure 2, a typical on/off  
19 response curve is exemplified. The limitations of this  
20 control method are the system lag time and loading. In most  
21 industrial applications, ON/OFF control always overshoots the  
22 setpoint both on the increase and decrease of the measured  
23 signal. In the disinfection control example, when the HRR



1 exceeds the setpoint, the chemical fed to the system stops,  
2 but the mixing and distribution of the chemical fed during  
3 the lag time continues to increase the system's HRR. This  
4 sinusoidal response is very typical for this control method.  
5 Restricting the flow rate of chemical to the system can  
6 minimize the sine wave amplitude, however during high load  
7 events the chemical feed will be unable to meet the demand.  
8 The result is that some overshoot is accepted as the  
9 limitation of an inexpensive (and simple) control method.

10 As particularly illustrated in Figure 3, the height of  
11 the first peak will vary based upon the response time of the  
12 system, and the initial deviation from setpoint. The areas  
13 under the curve (above the setpoint) also represent wasted  
14 chemical.

15 Now referring to Fig. 4, typically Time Based  
16 Proportional response improves upon the simple control method  
17 by adjusting the feed rate of chemical based upon the  
18 measured signal's deviation from setpoint. In Time Based  
19 Proportional control, the ON time per minute of the output  
20 relay is varied based upon the measured signal's distance  
21 from setpoint. This is very similar to the P of P. I. D.  
22 control, except the output is not continuous. The advantage  
23 can be seen using the same disinfection example. If one

1 turns the Sodium Hypochlorite pump on for 10 seconds and off  
2 for 50 seconds when you are only 1 mV below the desired HRR,  
3 the rate of HRR rise will be far less per minute and the  
4 overshoot will be minimal. Figure 4 illustrates the output  
5 feed ratio of time based proportional control throughout the  
6 proportional band. The benefit of time based proportional  
7 control is a more consistent disinfection rate (less  
8 corrosion and fouling), and chemical is conserved because  
9 chemical is not being fed to exceed the desired disinfection  
10 rate.

11 With reference to Figure 5, the ideal response of a Time  
12 Based Proportional control system is illustrated.

13 Proceeding to Figure 6, while Time Base Proportional  
14 control is an improvement over ON/OFF control, it still has  
15 certain limitations. With large fluctuations of loading,  
16 Time-based proportional control may not increase the output  
17 enough to compensate. Using the disinfection example again,  
18 when an increased loading condition occurs, the controller  
19 using Time Based Proportional control will proportion the  
20 output to increase the Sodium Hypochlorite feed rate to the  
21 system. But as the HRR starts to rise, the controller will  
22 reduce the output at the same ratio as the previous loading.  
23 The result is a setpoint that may never be achieved, because

1 it now takes more Sodium Hypochlorite to maintain the same  
2 HRR (due to loading).

3 In order to address the inability of a time based  
4 proportional control system to achieve setpoint during a  
5 loaded condition, the instant invention incorporates an  
6 additional response into Time-based proportional control that  
7 will compare the measured signal to the setpoint with respect  
8 to time, and increase or decrease the output time ratio (duty  
9 cycle) to compensate for loading as needed. This is  
10 accomplished by increasing or decreasing an offset value  
11 applied to the control setpoint.

12 Figure 7 depicts the programmed response of the Time  
13 Based Proportional control with the addition of selected time  
14 duration response. The rate of change would be tied  
15 proportionally to the deviation from setpoint and may be  
16 adjustable with software. The time base used for the  
17 selected time duration response would be different (usually  
18 longer) than the proportional time base, is generally set  
19 forth as a multiple thereof, and can also be adjustable.  
20 Typically, in the recirculated systems currently controlled  
21 by time based proportional control, the selected time  
22 duration response time base would about 5 minutes.

23 Referring to Figure 8, the figure is illustrative of the

1 expected time-based proportional control with selected time  
2 duration response in a typical HRR loading situation as  
3 described in the text above. As is readily appreciated, this  
4 curve closely mirrors the ideal proportional control response  
5 as set forth in Figure 5.

6 Now referring to Figures 9 and 10, the inclusion of  
7 integration logic within the standard proportional logic feed  
8 up is exemplified. Figure 9 is illustrative of a feed up  
9 example utilizing timed base proportional logic, absent  
10 selected time duration response logic. Figure 10,  
11 specifically the area within the block 1010, modifies the  
12 prior art proportional logic mode of operation by utilizing a  
13 form of deviation compensation, for example by including  
14 selected time duration response logic, which may be  
15 manifested as integration of a signal, so as to achieve an  
16 automatic offset of the time based proportional control  
17 function. The signal must first be verified to be residing  
18 within the chosen proportional band width, and it must be  
19 further confirmed that the signal is within a particular  
20 hysteresis value about the desired setpoint. If the signal  
21 is found to be outside of the hysteresis value of setpoint,  
22 then a determination must be made as to whether the signal  
23 falls within the category of being either steady or

1     retreating from the setpoint during the integral time  
2     duration. If the determination is affirmative, then a change  
3     in the offset is carried out based upon selecting a value,  
4     herein termed the "offset sensitivity value" or OS and  
5     multiplying it by the value of deviation from setpoint.  
6     Inclusion of this subroutine idealizes the time based  
7     proportional response.

8             Ranges of typical values for the calculation of the  
9     formulas are as follows:

10    Proportional Band Width (PB) is typically 30 or 60 mV with an  
11    allowable range between about 5 and 500 mV. .50 pH units is  
12    typical with an adjustable range between about .10 and 5.00  
13    pH units. From about 100 to 500 microsiemens is typical with  
14    an adjustable range between about 10 and 5000 microsiemens.

15    Time Base(TB): typically 30 or 60 seconds with an adjustable  
16    range between about 15 and 600 seconds

17    Signal(SIG): HRR typical range is 0-1000 mV with an instrument  
18    maximum range of -1500 to +1500, pH typical control range of 2-  
19    12 pH with an instrument maximum range of 0.00-14.00 pH.  
20    Conductivity typical range is 1000-5000 microsiemens with an  
21    instrument maximum range of 0-10,000 microsiemens.

22    Setpoint(SP): HRR is application dependent but is generally  
23    within the range of about 150 to 780. The pH will typically be

1 between 2 and 12 pH with the greatest majority of applications  
2 (90%) within the 6.00-9.00 pH range. Conductivity setpoints  
3 are generally between 1000 and 4000 microsiemens.

4 Hysteresis values for HRR are 0-10 mV with .02 typically used.

5 Hysteresis for pH is typically .02 or .1 with a range of 0.00-  
6 1.0 pH. Conductivity hysteresis is usually 10 but can range  
7 from 0 - 1000.

8 Offset Sensitivity Value (OS) is a percentage or fractional  
9 percentage with a range between 0 and 100%. The Setpoint

10 Offset Value (SOV) is calculated by taking the Sustained  
11 Deviation From Setpoint (SD) as a fractional percentage of the  
12 Proportional Band (PB) multiplied by the Offset Sensitivity  
13 Value (OS) times the Proportional Band, according to the  
14 formula:  $SOV = (SD/PB) * OS * PB$

15 Example: SD= 10 mV; PB = 30 mV; % of PB = .33;

16 if Offset Sensitivity Value = 1.00 then setpoint offset would  
17 change by  $.33 * OS * 30$  or 10 mV. If OS=.5 then setpoint offset  
18 would be 5 mV.

19 It is to be understood that while a certain form of the  
20 invention is illustrated, it is not to be limited to the  
21 specific form or arrangement of parts herein described and  
22 shown. It will be apparent to those skilled in the art that  
23 various changes may be made without departing from the scope of

1 the invention and the invention is not to be considered limited  
2 to what is shown and described in the specification and  
3 drawings.

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CLAIMS

What is claimed is:

Claim 1. A process for time-based proportional control of chemical values in a water treatment system wherein a measured signal value is generated, comprising the steps:

selecting an offset sensitivity value; and  
calculating a setpoint offset value (SOV) to determine said measured signal value;

wherein said measured signal value approximates an ideal proportional control response.

Claim 2. A process in accordance with claim 1 wherein:  
said setpoint offset value is calculated according to the formula

$$SOV = (SD/PB) * OS * PB$$

where SD equals the sustained deviation from setpoint

PB equals Proportional Band Width

OS equals Offset Sensitivity Value.

Claim 3. In a process for time-based proportional control of chemical values in a water treatment system wherein a



1 measured signal value is generated, the improvement comprising:

2 modifying said measured signal value to be within a range  
3 defined by a particular proportional band width;

4 verifying that said signal value lies within a hysteresis  
5 value about a particularly defined setpoint;

6 measuring said signal value to confirm that said signal  
7 value is steady or retreating from said setpoint during a  
8 selected time duration ;

9 selecting an offset sensitivity value; and  
10 calculating a setpoint offset value (SOV) according to the  
11 formula

$$12 \quad SOV = (SD/PB) * OS * PB$$

13 where SD equals the sustained deviation from setpoint

14 PB equals Proportional Band Width

15 OS equals Offset Sensitivity Value;

16 wherein said measured signal value approximates an ideal  
17 proportional control response.

18  
19 Claim 4. A process in accordance with claim 3 wherein:  
20 said particular proportional band width is between about  
21 5 and 500 mV.

22  
23 Claim 5. A process in accordance with claim 3 wherein:

1        said particular proportional band width is between about  
2        0.1 and 5.0 pH units.

3  
4        Claim 6. A process in accordance with claim 3 wherein:  
5        said particular proportional band width is between about  
6        10 and 5000 microsiemens.

7  
8        Claim 7. A process in accordance with claim 3 wherein:  
9        said time base is between about 15 and 600 seconds.

10  
11       Claim 8. A process in accordance with claim 3 wherein:  
12       said selected time duration is a multiple of the time  
13       base.

14  
15       Claim 9. A process in accordance with claim 3 wherein:  
16       said hysteresis value is between about 0 and 10 mV.

17  
18       Claim 10. A process in accordance with claim 3 wherein:  
19       said hysteresis value is between about 0 and 1.0 pH units.

20  
21       Claim 11. A process in accordance with claim 3 wherein:  
22       said particular proportional band width is between about  
23       0 and 1000 microsiemens.

1 Claim 12. A process in accordance with claim 3 wherein:  
2 said setpoint is between about 150 and 780 mV.

3  
4 Claim 13. A process in accordance with claim 3 wherein:  
5 said setpoint is between about 2 and 12 pH units.

6  
7 Claim 14. A process in accordance with claim 3 wherein:  
8 said setpoint is between about 1000 and 4000 microsiemens.

9  
10 Claim 15. A process in accordance with claim 3 wherein:  
11 said offset sensitivity value is within the range of about  
12 0 and 100 percent.

ABSTRACT

The instant invention is a device and method for its use which includes the addition of a deviation compensation function effective to automatically adjust the offset used in time-based proportional control. Inclusion of this improvement finds particular utility in situations like public pools where daily bather load varies depending on weather and other unpredictable factors.

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FIG. 1

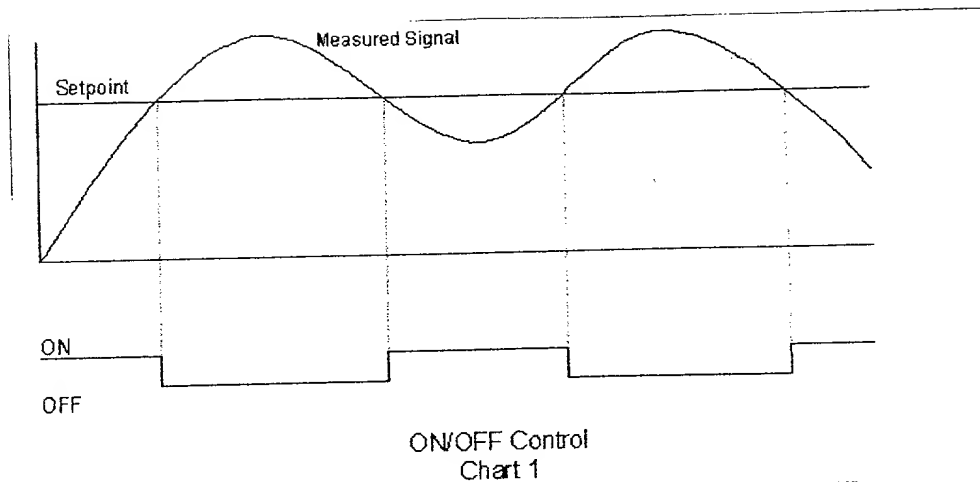


FIG. 2

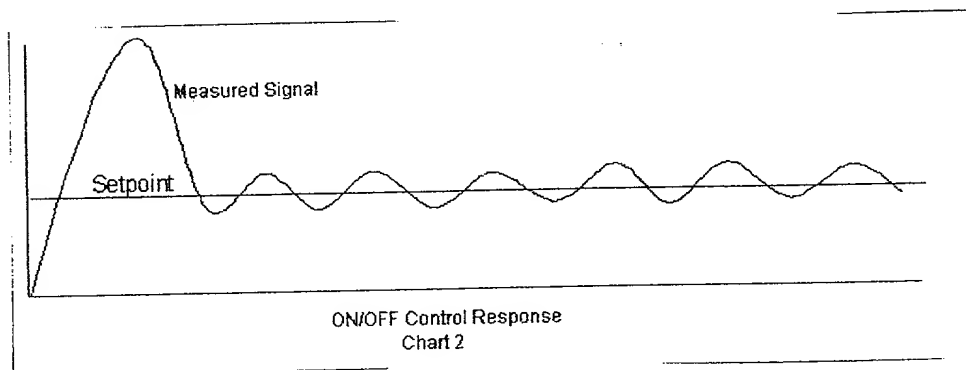


FIG. 3

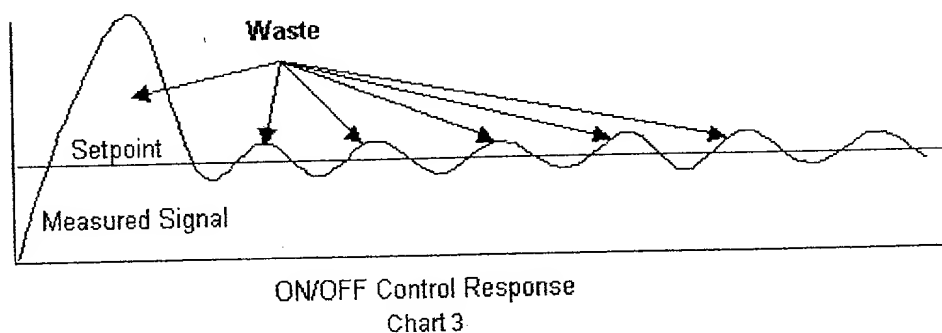
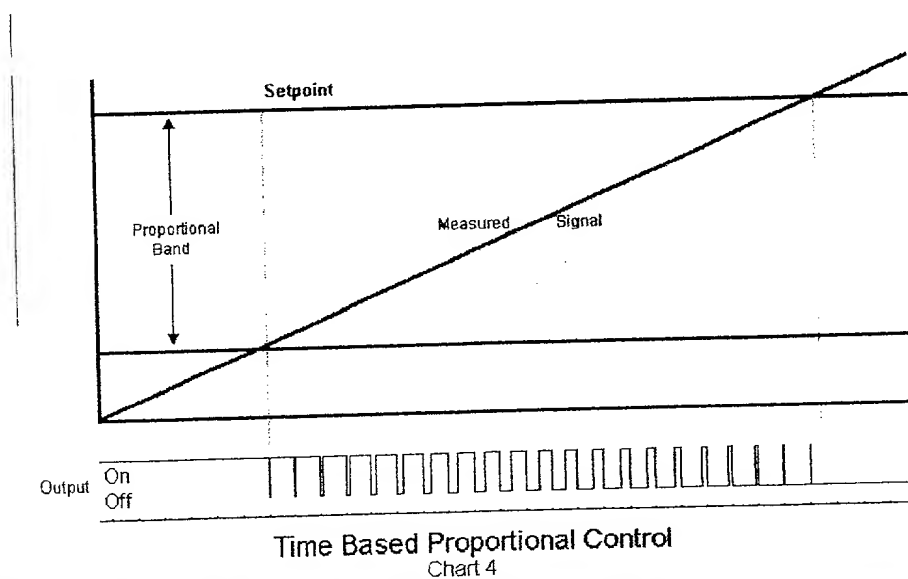


FIG. 4



Note the on/off ratio change as the signal approaches setpoint

Chart 5 shows the ideal response of a Time Based Proportional control system.

The chart shows a horizontal line at the top labeled 'Setpoint'. A curve labeled 'Measured Signal' starts at the origin (0,0) and rises smoothly, asymptotically approaching the setpoint line. The curve is concave down, indicating a decreasing rate of change as it approaches the setpoint.

The graph illustrates the behavior of a Time Based Proportional with Integration control system. The vertical axis represents the 'Proportional Band' and the horizontal axis represents 'Time'. The signal starts at the bottom left and rises linearly, reaching the top of the proportional band. The signal is labeled 'Measured Signal'. The graph is divided into sections by vertical lines. The first section is labeled 'On' and 'Off' on the y-axis. The second section is labeled 'Time Based Proportional' and 'Integration' on the x-axis. The third section is labeled 'Setpoint' at the top. The signal is labeled 'On' and 'Off' on the y-axis. The signal is labeled 'Time Based Proportional' and 'Integration' on the x-axis. The signal is labeled 'Setpoint' at the top. The signal is labeled 'Measured Signal'.

Measured Signal

Expected Time Based Proportional with Integral Response (under load)

Chart 8

# Time Based Proportional Logic - Feed Up Example

PB= Proportional Bandwidth  
 SIG=Signal from Sensor  
 SP=Setpoint  
 TB= Time Base  
 TBP= Time Based Proportional

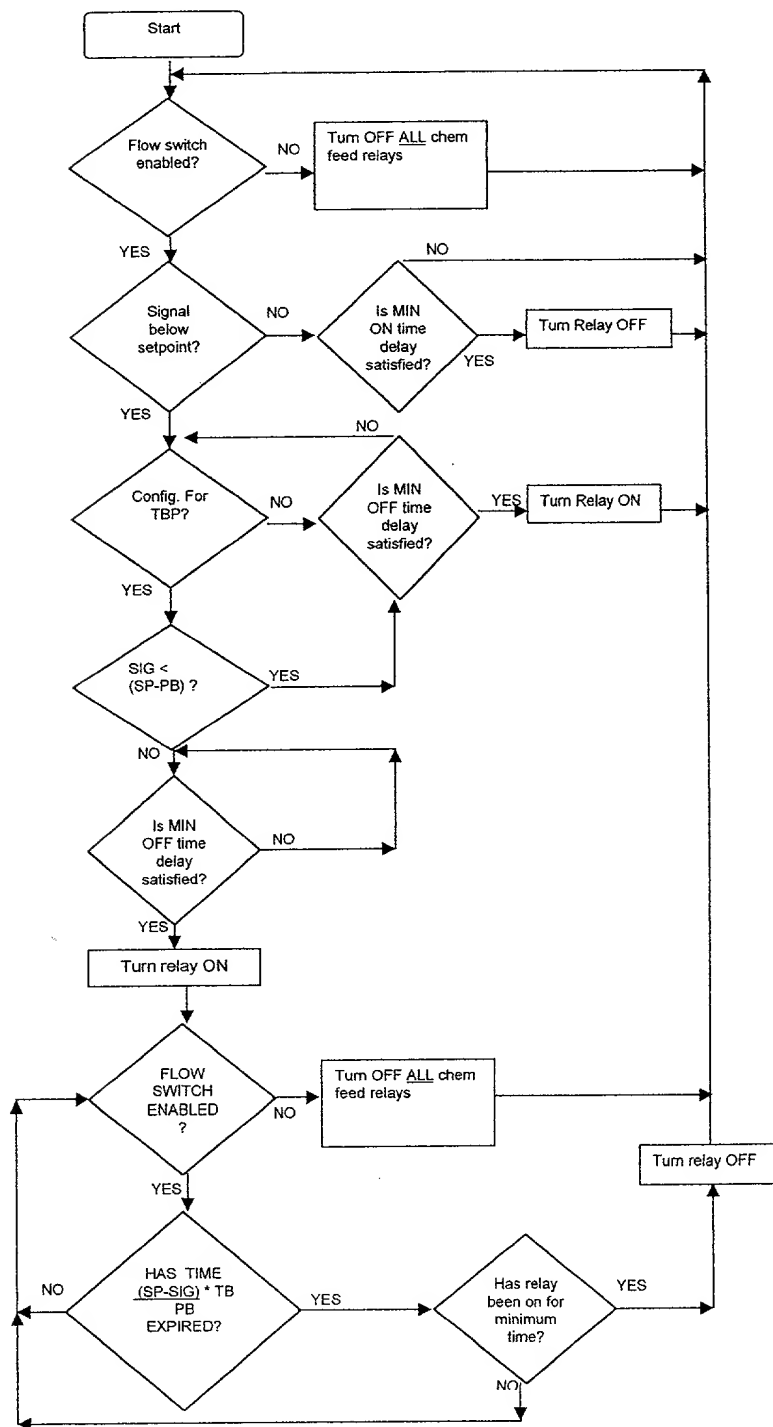


FIGURE 9

# Time Based Proportional with Integration Logic - Feed Up Example

SP=Setpoint PB= Proportional band  
SIG=Signal TB=Time Base  
TBP=Time Based Proportional

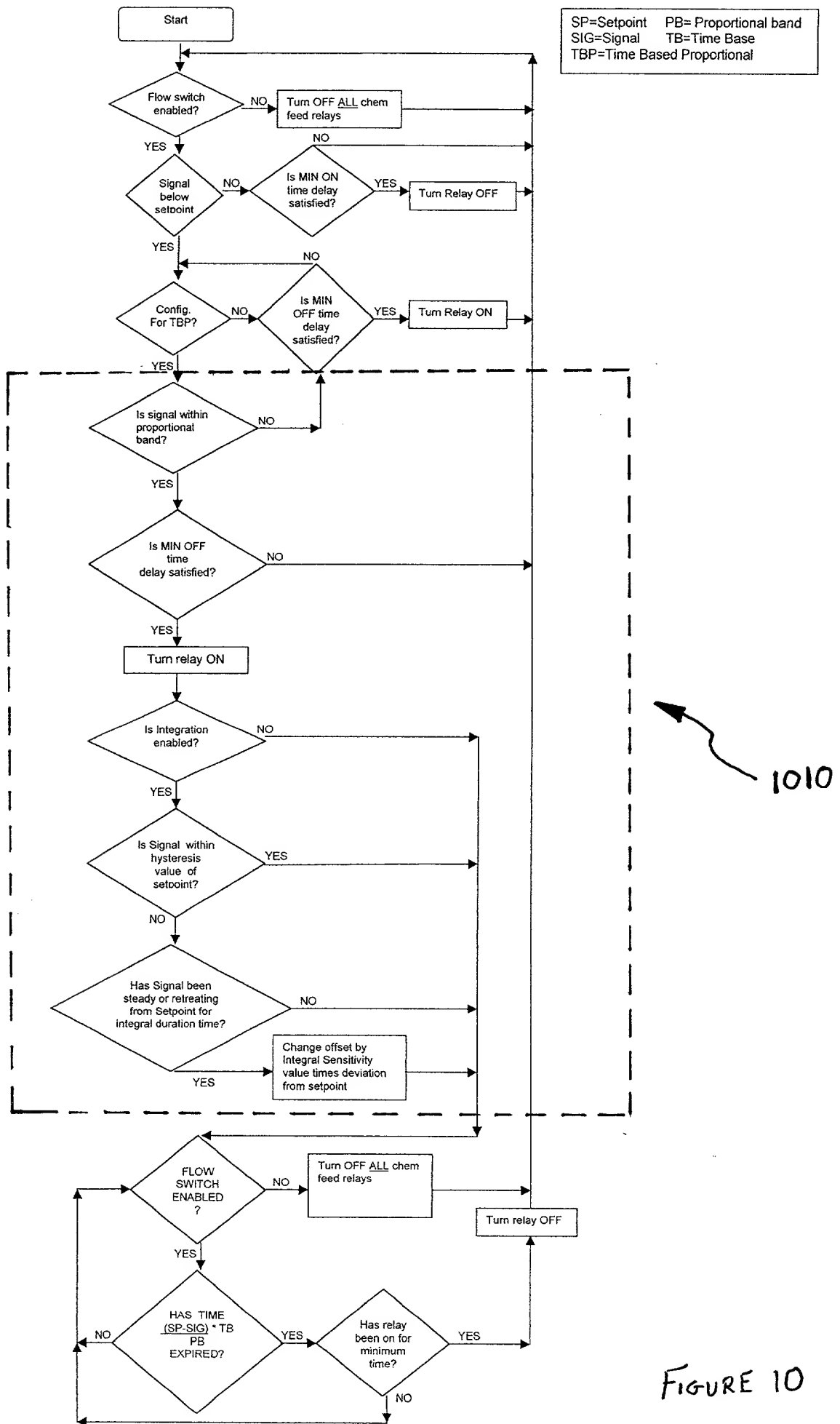


FIGURE 10



**DECLARATION FOR UTILITY OR DESIGN  
PATENT APPLICATION (37 CFR 1.63)**

**Attorney Docket No.: 1519.018**

**Inventor Name:** Richard W. Dennis, II

**COMPLETE IF KNOWN**

☒ Decl. Sub. w/Initial Filing  
☐ Decl. Sub. after Initial Filing (surcharge (37 CFR 1.15 (e)))

Application No: /  
Filing Date:  
Group Art Unit:  
Examiner Name:

As a below named inventor, I hereby declare that:

My residence, post office addr., and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**ENHANCED TIME-BASED PROPORTIONAL CONTROL**

the specification which

☒ is attached hereto OR  
\_\_\_\_\_ was filed on \_\_\_\_\_ As United States Application No. or PCT Intl. Appln. No. \_\_\_\_\_ and was amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN NUMBERS:	COUNTRY:	FOREIGN FILING DATE:	PRIORITY NOT CLAIMED:	CERTIFIED COPY Yes	No
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Additional foreign appln. nos. are listed on a supplemental priority data sheet PTO/SB/02B attached hereto,

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below:

**APPLICATION NUMBER(s):** \_\_\_\_\_ **FILING DATE:** \_\_\_\_\_

\_\_\_\_\_ Addnl. provisional appln.  
Nos. are listed on a  
Supplementary priority data  
Sheet PTO/SB/02B attached.

**DECLARATION - UTILITY or DESIGN PATENT APPLICATION**

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

U.S. PARENT APPLICATION  
or PCT NUMBER:

PARENT FILING DATE:

PARENT PATENT NO:  
(if applicable)

Additional U.S. or PCT international appln.nos. are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: X Customer No: 21917 PLACE CUSTOMER No.  
BAR CODE LABEL HERE

OR

Registered practitioner(s) name/registration no. listed below.

NAME:	REGISTRATION NO:	NAME:	REGISTRATION NO:
Michael A. Slavin	34,016		
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DIRECT ALL CORRESPONDENCE TO: Customer Number OR  
Or Bar Code Label Correspondence address below

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 17 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR: A Petition has been filed for this unsigned inv.

GIVEN NAME (first and middle (if any)):

FAMILY NAME OR SURNAME:

Richard W.

Dennis, II

Inventor's signature: [Signature] Date: 12 JUN 00

Residence: P.O. Box 35

City: Clifton State: IL 60927 Country: US Citizenship: US

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Additional inventors are being named on the Supplemental additional inventor(s) sheet(s) PTO/SB/02A attached hereto.